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The Editor's Page

Tercentenary of U. S. Chemical Industry

UNIVERSALLY acknowledged as one of the giants of modern industry, and one of the ripest fruits of fundamental research, the chemical industry of the United States is to celebrate formally and fittingly the tercentenary of its founding, and thus take its place among the oldest of domestic industries.

It was John Winthrop, Jr., first colonial governor of Connecticut and son of the Pilgrim governor of Massachusetts, who in 1635 planned an ambitious program for the domestic production of a large variety of chemicals required by industry and medicine, and who also established the first chemical laboratory and library in this country.

To adequately celebrate this 300th anniversary the American Chemical Society, at its 89th meeting in New York, April 22, will inaugurate a series of events in which it will have the cooperation of the Synthetic Organic Chemical Manufacturers Association, the Manufacturing Chemists Association and the chemical societies of the metropolitan district. Hon. Francis P. Garvan, president of the Chemical Foundation and the U. S. Institute for Textile Research, and recipient of the Priestley Medal as "the greatest lay patron of chemistry," is honorary chairman of the New York committee organizing the celebration.

While eminent speakers will trace, at meetings to be held during the week, the wonderful progress and accomplishments of the chemical industry for 300 years, there should be an opportunity at one of these meetings for an accredited representative of each of the great basic industries formally and publicly to confess the great debt that they owe to the chemical industry, and thus indirectly to research which is the foundation of chemical progress.

Effect of Wear and Laundering on Cotton Sheeting

By LAWRENCE B. HALEY *

Summary

Wide cotton sheets were placed in service and laundered weekly. Chemical and physical tests were made on the sheets at successive wear intervals.

The physical properties of the sheets, namely, strength, weight, thickness and air permeability, were found to be more adversely affected in the area exposed to the greatest wear. Copper number and alpha-cellulose determinations showed the chemical deterioration to be greatest in this same portion of the sheet. Photomicrographs showed the greatest change in the physical appearance of the sheets occurred in this area.

This evidence indicates that wear either has a chemical action or so changes the physical condition of the material that the chemical effect of laundering is increased. It follows, then, that the effect of wear or abrasion is much greater than has been assumed by previous investigators and that this effect must be considered in judging the wearability of cotton sheets.

Introduction

THE wearability of cotton fabrics is of undoubted interest to both manufacturers and consumers. This property in sheets is affected by two factors: wear in use, and laundering, and they must be considered jointly. Several investigators have studied only the effect of laundry action on this fabric, while others have studied the effect of both wear and laundering. In this previous work, however, the stress seems to have been on laundering rather than use. The present investigation emphasized wear and included a study of the effect of wear and laundering on the following properties of sheets: fabric strength, fibre strength, weight, thickness, air-permeability, copper num-

* Mr. Haley as a Junior Fellow of the Textile Foundation worked under Prof. H. B. Gordon, Alabama Polytechnical Institute, Auburn, Ala.

ber and alpha-cellulose content. Plain cotton sheeting was chosen as the fabric for study since the construction is simple and the wear may be relatively easily controlled.

Method of Wear

Ten sheets, 90 x 108 ins.,* were put into service as the lower sheet and used by two people. The wide hem was always placed at the head of the bed. This assured maximum wear, since, on the average, most sheets are used as the lower sheet only half the time. The sheets were laundered weekly by a commercial laundry.†

Each sheet was numbered and a record kept of the number of times it was laundered. The sheets were kept in continuous service until removed for testing or because of failure.

Method of Laundering

The washing procedure followed throughout the study was as follows: A 15-minute wash with water at a temperature of 90–100° F. was followed by two 10-minute washes with soap solution (¼ lb. neutral soap chips and ⅛ lb. soda ash to 8–10 gallons of water), the temperature being 140–160° F. The soap washes were followed by 5-minute rinses with water at 160–180° F. and a final rinse with cold water containing a trace of aniline blue. The sheets were extracted 10–15 minutes with centrifugal force and then ironed on a six-roll mangle (65–70 lbs. steam pressure).

Method of Sampling

Samples were taken from both the inner and outer portions of the sheets. The test specimens from the inner portion were taken from the area of probable maximum wear[1] and those from the outer portion were taken at least two inches from the selvedge. Similar samples were also taken from the new sheets. Before testing, all samples were conditioned for two days in a room maintained at 65% relative humidity and 70–80° F.

Method of Test

The grab rather than the strip method was used for determining the breaking strength of the fabric, since it appears to represent more nearly the tearing action to which a sheet is subjected during use. Samples of 4 x 6 ins. were broken in a vertical pendulum-type tester of 150–300 lbs. capacity. This tester was motor driven, the lower jaw traveling down at the rate of 12 ins. a minute. The jaws were 3 ins. apart, the back jaws 3 ins. wide and the front jaws 1 in. Warp and filling pieces were broken and the average of 10 determinations is shown in Fig. 1.

Thickness was measured by a Randall-Stickney micrometer graduated to .001 in. Readings were made to the nearest ¼ division and the average

* The sheets and 40 yards of sheeting were given by Minot, Hooper & Co., through Mr. Hillyer.

† The laundering was done through the courtesy of Mr. C. J. Young, Auburn, Ala.

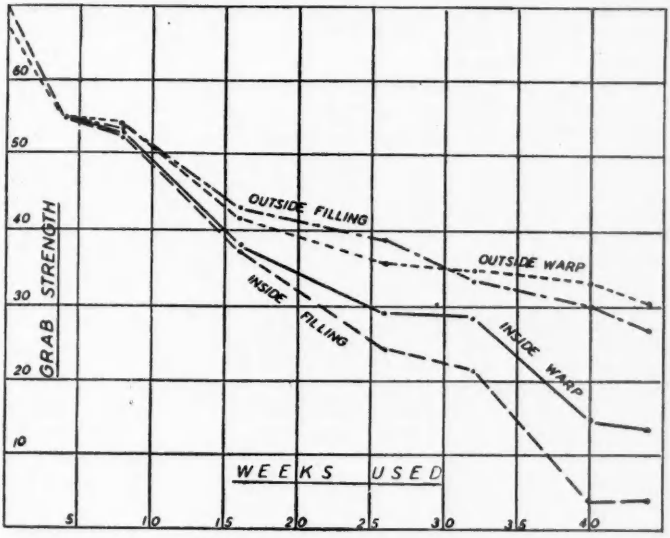

FIG. 1

of 10 readings reported. Thread count was determined with the aid of a one-inch pick lens, the average of five observations being recorded.

For determination of fibre strength, the method of Gordon [5] was used with the modification suggested by Clegg.[6] In this method a fibre is mounted across a hole in paper and fixed with a drop of cement.* This paper is then placed in the jaws of the tester and cut so as to leave the fibre free, after which the strength of the fibre is determined.

The apparatus described by Shiefer and Best [4] was used in obtaining the values of air-permeability of the sheets. These values are expressed in cubic feet per minute per square foot of fabric for a pressure drop of one-half inch of water.

For copper number determinations the micro-method described by Doree [2] and Heyes [3] was used. The results were calculated to correspond with the usual meaning of copper number; *i.e.*, grams of copper reduced by 100 grams of air-dry cellulose.

The method of Gortner and McNair [10] was used for determining the alpha-cellulose content of the different portions of the sheets, the material first being disintegrated in a Wiley mill. Although this method calls for the use of oven-dry samples, in this study conditioned samples were used in order to prevent possible damage from drying. The moisture content of the conditioned material was determined by drying for 48 hours at a

* Duco Household Cement was found to be excellent for fixing the fibres to the paper.

temperature of 105–110° C. The alpha-cellulose values reported are based on the weight of the bone-dry material.

Discussion

The physical appearance of the sheets at successive wear intervals is illustrated by the photomicrographs in Figs. 13 and 14. All the quantitative data are reported graphically in Figs. 1 to 12.

It was found that the sheets used in this study became wider and shorter as the length of service increased. The width increased about 6% and the length decreased approximately 8% during 44 weeks of continuous wear. A corresponding change in thread count was also noted. Apparently this change is caused by ironing the sheets from selvedge to selvedge. This conclusion has also been reported by other workers.[7, 8] Since the sheets are pulled in the filling direction to insure proper ironing, the filling threads are subjected to a greater strain than occurs on the warp threads in this process. This stretching may explain, in part, the greater weakness noted in the filling threads after use. Failure of the sheets studied was due to lengthwise tears in all cases (Filling yarn failure).

As shown in Fig. 1, the order of fabric strength after the maximum period of use is: outside warp, outside filling, inside warp, inside filling, and there is apparent a definite reduction of strength in the samples from the inside portions as compared with the outside portions throughout the entire period of wear.

The weight was found to be less for the inside portion after wear, as shown in Fig. 4, which also shows the initial increase in weight caused by shrinkage. There was a gradual loss of weight after eight-weeks use and it appears that after the weight loss of the inner portion reaches 25% the sheets are no longer serviceable. A similar conclusion was also reached by an earlier investigator.[8]

It may be observed from Fig. 3 that the thickness had an initial increase because of laundering. This was to be expected since the fabric had probably been compressed in the finishing process before it was sold. After 4-weeks use the thickness gradually decreased, the inner portion becoming thinner than the outer. The thickness of the inner portion decreased more rapidly than that of the outer portion. Other investigators[7, 8] have found no regular trend in thickness changes during the life of sheets; yet a very definite trend in the thickness of the sheets under test is shown in Fig. 3.

The copper number of the inner portion increased much more rapidly than did that of the outer portion. The change in this property as the length of service increased is illustrated in Fig. 5. The relation of copper number and fabric strength is shown in Fig. 8.

The alpha-cellulose content of the outer portion of the sheet remained constant throughout the 44-weeks of service, varying within a range of about 2%, as shown in Fig. 12. However, the alpha-cellulose content of the inner portion decreased about 4–5% during the period of test and was always slightly less than the corresponding values for the outer portion. This change in alpha-cellulose content, as might be expected, is not nearly so great as was the change in the other properties studied.

Despite the seemingly erratic nature of the curves shown in Fig. 2, the strength of single fibres taken from the most-worn sheets is definitely

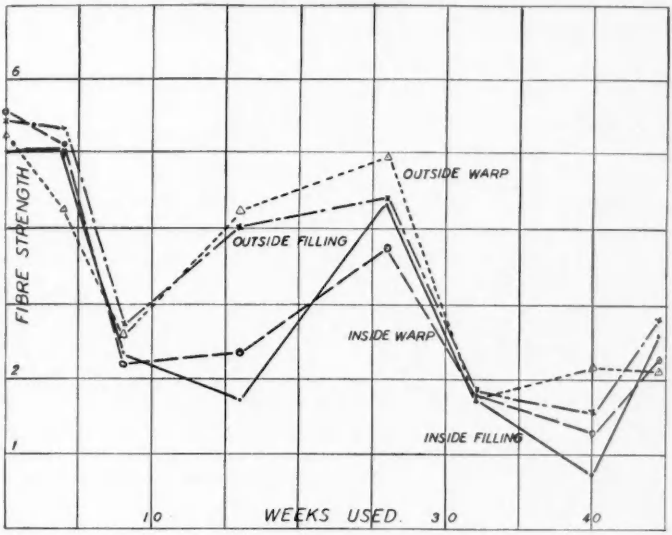
6
2
1
FIBRE STRENGTH
OUTSIDE WARP
OUTSIDE FILLING
INSIDE WARP
INSIDE FILLING
10
WEEKS USED
30
40

FIG. 2

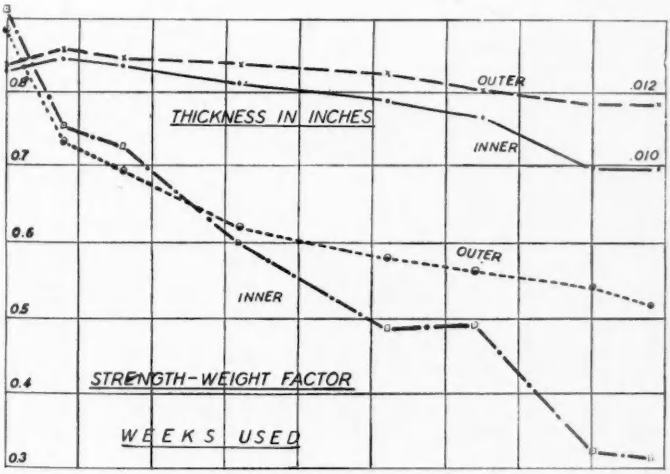
0.8
0.7
0.6
0.5
0.4
0.3
THICKNESS IN INCHES
OUTER
.012
INNER
.010
OUTER
INNER
STRENGTH-WEIGHT FACTOR
WEEKS USED

FIG. 3

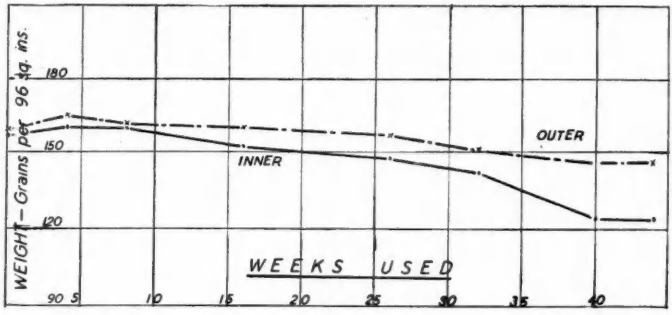

FIG. 4

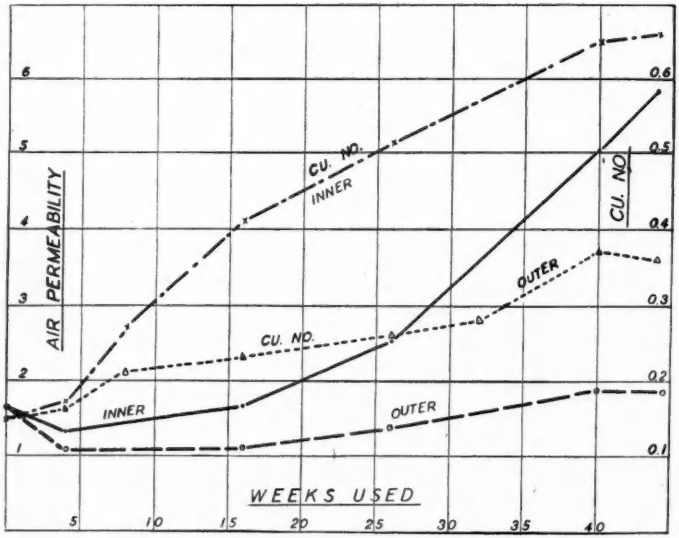

FIG. 5

less than the strength of fibres taken from new sheets. It should be noted that after continued use the fibres in many cases are broken, and since it is not convenient to use very short fibres in making the strength test, the longer ones were naturally selected. This gave strength values probably higher than the true ones.

The air-permeability at first increased. This was probably caused by shrinkage. As the sheets were used, however, there was a small but con-

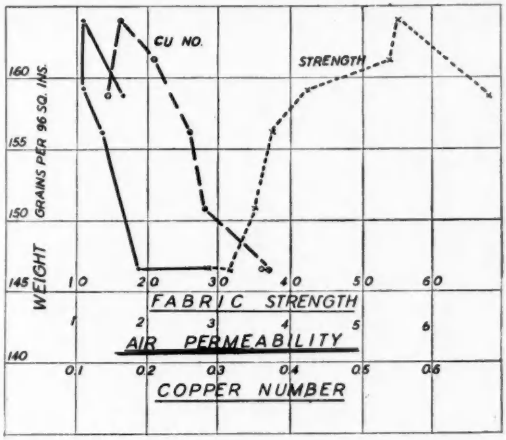
CU NO.
STRENGTH
160
155
150
145
140
WEIGHT
GRAINS PER 96 SQ. INS.
10
20
30
40
50
60
FABRIC STRENGTH
1
2
3
4
5
6
AIR PERMEABILITY
0.1
0.2
0.3
0.4
0.5
0.6
COPPER NUMBER

FIG. 6

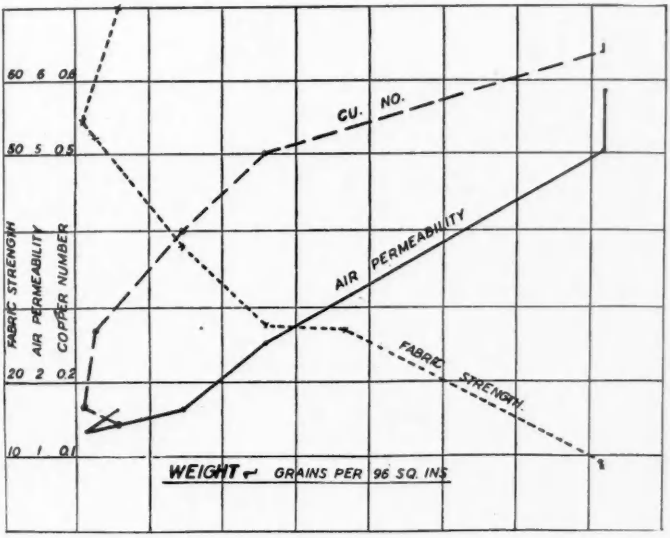
60 6 0.6
50 5 0.5
20 2 0.2
10 1 0.1
FABRIC STRENGTH
AIR PERMEABILITY
COPPER NUMBER
CU. NO.
AIR PERMEABILITY
FABRIC STRENGTH
WEIGHT GRAINS PER 96 SQ. INS.

FIG. 7

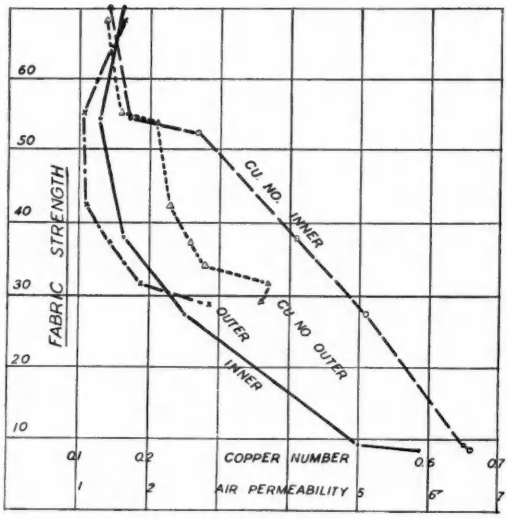

FIG. 8

tinued increase in the permeability of the outer portion of the sheets, the values for the inner portion increasing much more rapidly, as shown in Fig. 5. There was a distinct difference in the air-permeability of the two portions even after only 4-weeks use. This indicates that this means of test might be of value as a measure of wear.

The advantage of air permeability tests in the study of fabric wear would be that the same sample could be tested after successive wear intervals, a procedure not possible with methods which destroy or mutilate the material being tested. This would require changes in the design of the present apparatus, but these could doubtless be easily made. The method has the further advantage of rapid and simple operation.

It may be readily understood from Fig. 14a and 14b why the air permeability increases so much as the fabric is subjected to wear and laundering.

Frequently the effect of actual abrasion on the wearing out of sheets is overlooked or ignored, only the laundry action being considered. Recently a leading retail firm laundered its sheets 364 times before judging them to be worn out. In this instance, however, the sheets were not actually placed in service. Undoubtedly the abrasion of actual use, coupled with laundering, will materially lessen the time of service. One investigator reported[8] that medium-weight sheets, when laundered after each night of use in a hotel (single bed), will last not more than about 250 washings. The results of the present study have conclusively proven that the effect of abrasion or wear is a most important factor in determining the wear-life

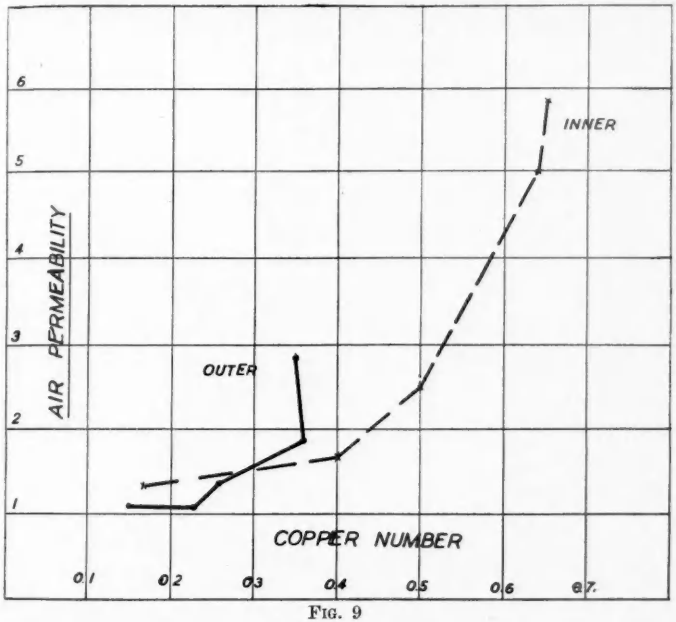

FIG. 9

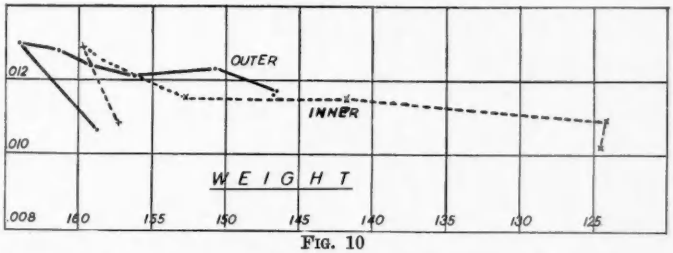

FIG. 10

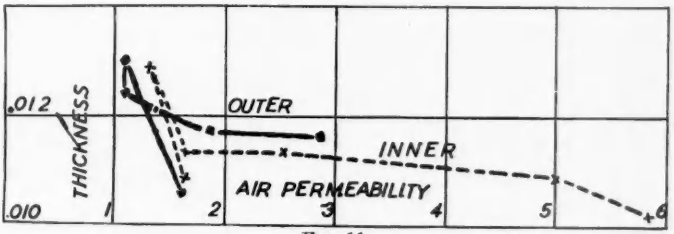

FIG. 11

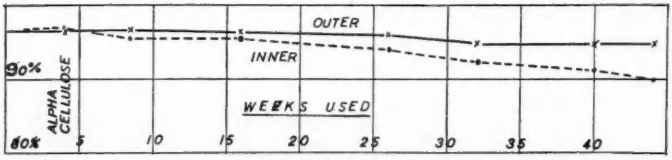

FIG. 12

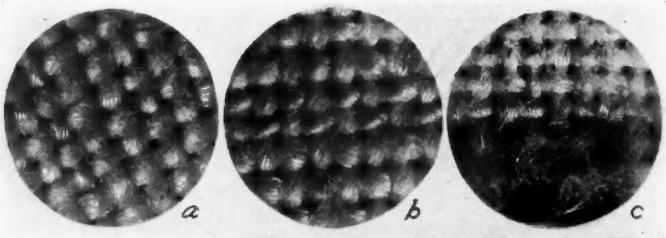

FIG. 13. Reflected light, (*a*) new sheet; sheet used 44 weeks, (*b*) outer portion, (*c*) inner portion.

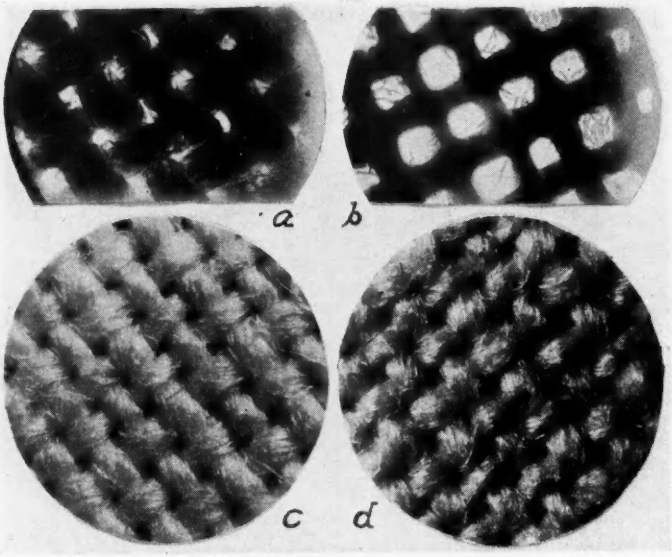

FIG. 14. Transmitted light, (*a*) new sheet, (*b*) sheet used 44 weeks. Reflected light, sheet used 26 weeks, (*c*) outer portion, (*d*) inner portion.

of a sheet. Under the conditions of wear and laundering described in this paper, it was found that the sheets were worn out at the end of about 50-weeks service.

Acknowledgment

This is to acknowledge the assistance of Walter T. Schreiber and Warren E. Emley, of the U. S. Bureau of Standards; of E. W. Camp, Chas. B. Ordway, C. L. Hare, C. A. Basore, P. P. Powell and L. J. Swertfeger, of the Alabama Polytechnic Institute; of R. W. Webb, of the U. S. Department of Agriculture, and Edward T. Pickard of the Textile Foundation. The author is particularly indebted to H. B. Gordon, formerly with the Alabama Polytechnic Institute, for suggesting and directing the study; and to H. J. Ball, of Lowell Textile Institute, for obtaining the data on air permeability.

Bibliography

1. Ruth O'Brien and Judith Steele. "Where Sheets Wear Out." *Tex. Wld.*, April 13, 1929.

2. Charles Doree. "The Methods of Cellulose Chemistry." D. van Nostrand, New York, 1933.

3. T. F. Heyes. *J. Soc. Chem. Ind.*, *47*, 90T (1928).

4. H. F. Shiefer and A. S. Best. "A Portable Instrument for Measuring the Air Permeability of Fabrics." *B. S. J. Rsch.*, Jan. 1932.

5. H. B. Gordon. "A Machine for Determining the Breaking Strength of Individual Textile Fibres." *Mell. Tex. Mo.*, Nov. 1933.

6. Gladys G. Clegg. *J. T. I.*, *15*, T 1 (1924).

7. M. Griffith and R. Edgar. "Deterioration of Five Wide Cotton Sheetings Due to Laundering." *J. Home Econ.*, *20*, 111–120 (1928).

8. "A Study of the Raw Cotton and the Yarn and Sheeting Manufactured from Three Grades of American Upland Cotton." *U. S. Dept. Agr. Tech. Bull.* No. 406.

9. J. McClew. "First Aid in Cotton Sheet Shrinkage." *Ntl. Laundry J.*, *102*, 5, 30–31.

10. "Quality Guides in Buying Sheets and Pillowcases." Leaflet 103, U. S. Dept. of Agric.

11. E. E. Chandler. "A New Method for Determining the Strength of Cotton." U. S. Dept. of Agric.

12. M. S. Furry. "Some Specifications of Wide Cotton Sheetings Bought on the Retail Counter." *Tex. Wld.*, *76*, 1169–71.

13. Furry and Edgar. "An Analysis of Wide Cotton Sheetings." *J. Home Econ.*, *20*, 429–442.

14. Anon. "What Laundry Tests Show About Sheetings." *Mod. Hosp.*, *24*, 390.

15. C. E. Carpenter. "Comparative Analysis of Nine Brands of Sheets." (Unpublished master's thesis. Copy on file with Home Economics Dept., University of Chicago.)

16. E. M. Miller. "An Analytical Study of Commercial Brands of Sheets." (Unpublished master's thesis. Copy filed with Home Economics Dept., University of Chicago.)

17. E. S. MacDonald. "Sheeting Durability Tests." *Bull.* Laundry-owners Natl. Assoc. U. S. and Canada and Amer. Inst. Laundering, *12*, 7, 7–8.

18. Associates for Gov't Service. "Service Tests for Bedsheets." The Cotton Textile Institute, Inc., New York.
19. Gortner and McNair. "Alpha-cellulose from Different Wood Sources." *Ind. Eng. Chem., 25,* 505–7.

Thixotropy

JUST how thixotropic are your emulsions? "This property," states the *Industrial Bulletin* of Arthur D. Little, Inc., "is now being considered in its relations to the uniformity, efficiency and stability of a variety of industrial products including adhesives, starch pastes, paints, and a number of pharmaceutical emulsions and food preparations. In a paper on this subject, read a few months ago in London, J. Pryce-Jones has presented a highly provocative and stimulating discussion.

"The term thixotropy refers to a reversible process whereby colloidal or gelatinous systems may, by shaking, stirring, or other mechanical means such as agitation by powerful sound waves, be transformed from a more or less solid jelly to a plastic or even fluid state, returning, however, after a period of rest, to the solid condition. The setting of fresh cream when it is allowed to stand in bottles or other narrow containers and the stirring of the thickened cream to facilitate pouring, is a familiar example. The fat globules are at first drawn together into a solid mass, but upon agitation are shaken apart and set in motion. The behavior of heather honey which, after setting, requires agitation to produce flow, provides another interesting illustration.

"Thixotropy bears an intimate relationship to the efficiency of film-forming or coating media. Paints, for instance, sometimes cause trouble through the settling out of pigments and the caking of deposits into hard settlements. A proper degree of thixotropy in this class of products is a definite aid in the establishment of uniformity and stability."

Micro-Analysis of Textile Fibres

Part III.—Observations on the Structure of Cotton

By G. GORDON OSBORNE *

Summary

The nature of the subject of this study, and the wide and general scope of the research, precludes the drawing of any specific conclusions in short sentence form. Certain generalities concerning cotton (already known or surmised) have been substantiated, while others have been rejected. In addition several minor aspects of cotton fibre composition are reported for the first time.

Certain sections of this paper, of particular interest to the reader, may be profitably studied alone, but to obtain an adequate conception of the full picture necessitates a reading of the entire paper. This is to be expected when it is recalled that the main purpose is to collect, analyze, and correlate the work of the past with the findings of the present study. As this field is so enormous, of necessity detailed information about one specific phase of it is not presented.

In summary outline the scope of the research is as follows: A detailed micro-analysis of the cotton fibre divides it into four main parts—cuticle, primary wall, secondary wall, and lumen. Each of these has been scrutinized carefully and descriptions of their component structure together with illustrative material are given. Reference has been made throughout to several theoretical aspects of the subject, while the final section of the report is devoted exclusively to a consideration of the fibre's molecular arrangement, growth mechanism, and intermicellar make-up.

Introduction

IN a previous paper [1] the physical structure, as revealed by microscopic investigation, of several types of bast fibre was given. The work has proceeded now to a point where the same

* Mr. Oborne, as a Senior Fellow of the Textile Foundation, worked under the direction of Prof. E. R. Schwarz, Massachusetts Institute of Technology, Cambridge, Mass.

story for cotton can well be presented. Before beginning, however, it is interesting to note that despite the relatively large and diversified amount of work already done on cotton this phase of actual physical construction and structure has not received the attention it warrants. Most of the knowledge we have of this subject comes by way of the exceptional work carried out by Balls [2] and his co-workers, first in Egypt on the physiology and genetics of the cotton plant, and later from his research endeavors for the Fine Cotton Spinners' and Doublers' Association, Ltd., in their manufacturing laboratory; and from H. J. Denham [3] of the British Cotton Industry Research Association. It seems surprising that such is the case, for a precise knowledge of the intimate structural make-up of the fibre (the basis of all cotton products) is needed if any scientific advance is to be made in the industry. This is as true for the research worker in this field as for the practical user of the fibre who attempts to improve or innovate his manufacturing organization in an intelligent manner to obtain new or more efficient results.

The work referred to reached its peak in the early twenties, since then little of new interest has appeared. An excellent resumé of the existing literature on this subject up to 1900 is given in Denham's first communication,[3] and his later work, together with that of Balls,[4] provides a review of the subject up to their own time of publication. In this paper reference will be made to existing work as needed and this will be supplemented by a fairly extensive bibliography.

The object of the present paper is to present the findings regarding the micro-structure of the cotton fibre to date in as complete a manner as possible, and will develop along these lines. A brief account of the growth of the fibre from the seed is followed by a more detailed report of the morphology of its four main parts, viz.: (1) cuticle; (2) primary wall; (3) secondary wall; (4) lumen. This in turn is followed by a description of the revealing action of polarized light and of its significance in showing the basic nature of the hair's structure. Finally a discussion section is added which considers the molecular arrangement, growth mechanism, and intermiceller make-up of the cotton fibre.

It will be noticed that throughout the work a constant effort has been made to observe the fibre in as natural a condition as possible. Certain reagents must, of course, be used to enable the study of otherwise undiscernible parts; and much concerning structure can be learned by watching disintegration and breakdown. But whenever possible the use of chemicals, stains, etc., has been avoided and the fibre left to appear as undisturbed and natural as possible. This, together with the simplicity of most of the techniques (already described [5]), should allow a ready understanding and easy duplication of the results.

Cotton Hair Growth

IT seems advisable, if not almost compulsory, in order to facilitate an understanding of subsequent discussions, to start the approach to this subject by an examination at the cotton plant itself. By beginning here, first with the boll and the growth of the hair from the seed coat, a clearer idea of the cotton fibre as it is known in practical usage will be obtained. For, in reality, the fibre of commerce is merely the desiccated product of an epidermal cell from the outer ovule coat of a cotton seed.

To illustrate and aid in the explanation of the manner of growth Fig. 1 is presented. The views of the new-sprung fibre are modifications of the work done by Farr; [6] the remainder are adaptations after the descriptions of Balls.[2]

The cotton seed itself is a complicated structure made up of three main parts. However, only one of these (the seed coat or husk) needs to be described in detail here, since it is interesting from the point of view of fibre development. Moreover, it is only the outer part of this coat and the cells in the very outside layer which give rise to the cotton fibre. Taken in its entirety, the coat in the growing seed is found to be formed of two closely appressed parts—an outer and inner layer. Each is composed of almost undifferentiated cells traversed by vascular tissue. In the ripe seed the coat becomes a horny, protective, double jacket consisting of the following: an epidermis; outer pigment or parenchyma layer; "crystal" layer (Krystallschicht); thick palisade layer; inner pigment layer; and the papery remnants of the endosperm. The function of the epidermal cells in the outer coat is best described by Dr. Balls: [2]

> "The ordinary epidermal cell of the outer ovule coat has a thick basal wall, separating it from the subepidermal layer, thinner side-walls, a thin cuticle covering the outer wall and dipping slightly between the side-walls, with a nucleus which is about one-fifth of the length of the cell, and small sap cavities in the protoplasm.
>
> "The outer wall of some of these cells bulges, their protoplasm becoming densely granular in the protuberance, while the nucleus moves up closely behind these granules. The swelling enlarges to about twice the diameter of the original cell, and the nucleus passes out into it with all the chromatin retracted into a large, deeply-staining, central nucleolus. The nucleus keeps at a short distance behind the tip of the swelling, or hair, which continues to elongate at the rate of about 1 millimetre a day, which may be expressed in terms of diameter as about twice the diameter added to the length on the average every hour."

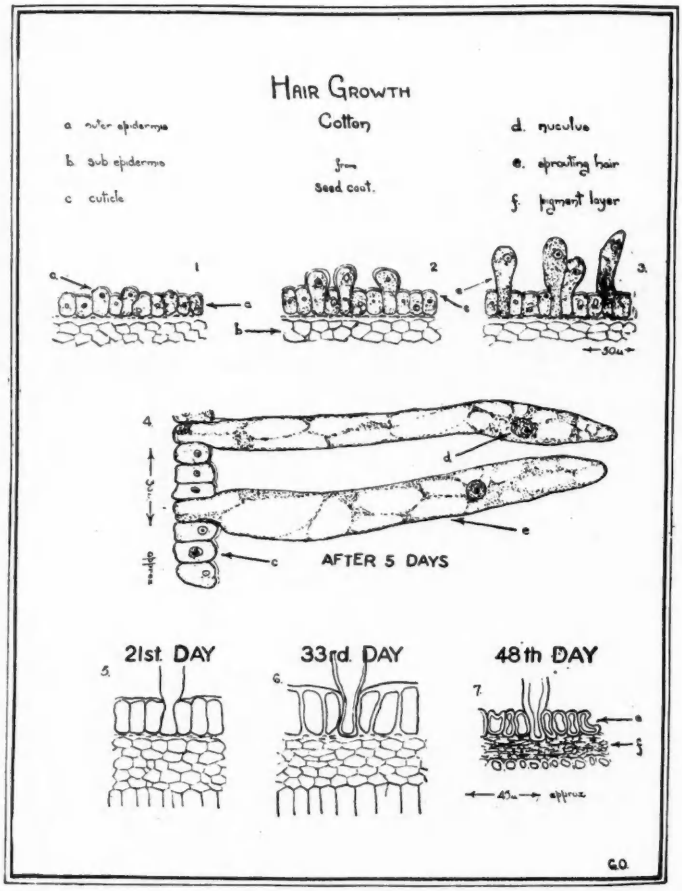

FIG. 1. Camera-lucida drawings showing various stages of cotton hair growth from the date of flowering to hair desiccation after boll opening.

Fig. 1 shows the lint or epidermal cells, the thick basal wall, the cuticle, and the sub-epidermal or parenchyma layer of the seed coat for the first three days of growth of the sprouting hair,* and (at a different scale) shows the young fibre at the end of the fifth day.

The full diameter of the fibre is reached almost at once; when it is only 100 μ long. It increases in length, however, unaccompanied by any cell division until approximately the 25th day, with a maximum of daily growth near the 15th day. During this enlargement process the extending cell wall consists of but a thin inner layer of cellulose (the Primary wall) encased in an all-enclosing film or cuticle, which in turn bears the natural waxes and oil. As the length-growth mechanism slows down and stops,† the fibre begins to exhibit another phase of growth (differentiation) and commences to thicken perceptibly. This is accomplished by the living protoplasm, which, having built the long hollow tube and held it distended by osmotic pressure, now proceeds to lay down, concentrically and centripetally, thin deposits of cell wall material. This secondary wall is largely cellulose and is arranged in an irregular helical pattern on the inside of the fibre, proceeding until the cell lumen is reduced to but a fraction of its original diameter. On approximately the 48th day the boll bursts, the protoplasm dies with accompanying drying up of the cell fluids, and further growth development terminates. The hairs now exposed to air and deprived of the internal turgid support of the cytoplasm, die and become desiccated. The cell walls collapse and assume the familiar and characteristic irregularly-alternating, spiral convolutions.

From flowering till the cessation of length growth and commencement of secondary thickening, there is little change in the outer ovule coat, although the palisade and epidermal cells of the inner layer increase tremendously in size. Such change in the former is merely a gradual enlargement in all the outer cells, with no change in the base of the hair. From the 21st day (when staining technique [2] shows the beginning of cell differentiation) the inner epidermis (crystal layer) of the outer coat enlarges and thickens rapidly. The unextruded lint cells swell even more and also thicken, while the separating, thin-walled parenchyma layer becomes disorganized to form the outer pigment layer of the fully ripened seed. (A similar but more emphatic metamorphosis takes place in the inner seed coat.) Fig. 1 shows these changes; in the outer ovule coat at approximately the 21st, 33rd and 48th day of development. (Particular attention should be focussed on the relative changes of secondary thickening in the basal part of the fibre.)

Thus it is evident that a single cotton fibre is but a simple unicellular trichrome, formed by the outward extension of a single cell from the outer ovule seed coat,‡ and distinguished by the characteristically great length-diameter relationship which in some species reaches the remarkable ratio of 6000:1.§

* Approximately the first 3 days since flower opening.

† Probably in part due to the confining limits of the now stationary ball.

‡ Why some cells form hairs while others remain to become part of the horny husk; and what determines the amount of growth (the "fibre" as distinct from the "linters") is not yet known. It is, however, interesting to note that the relative number of such sprouting cells over different areas of the seed and their respective length is chiefly governed by genetic factors; while the absolute number of such cells and their final length is seriously affected by environmental conditions.[4]

§ Compare Harland, S. C.—Jol. Trop. Agric. 6, p. 351, 1929.

Cuticle

The cotton hair, as with the epidermal cells of many plants, is covered with a cuticle. Although closely and firmly moulded to the primary wall during growth, it is not an integral part of it. The primary wall may just be resolved for inspection by critical magnification while the cuticle, many times thinner, is not detectable in this manner. This accounts for the fact that the lack of knowledge of this part of the fibre is greater than for the other components, and is most regretable, for, as the cuticle plays a major part in the surface attributes of the hair, it has a corresponding influence on spinning and yarn properties.

The presence of this thin surface-covering is best demonstrated by the use of stains or through chemical disintegration of the fibre. Thus Scharlach R with its high affinity for fatty substances (the waxes impregnating the cuticle) and Victoria Blue B, which leaves the cellulose untinted,[7] indicate its existence. Chemically, the characteristic strangulation points produced by the insoluble and non-swelling membrane in solutions such as $Cu(NH_3)_4(OH)_2$ are well known. (See Fig. 2.)

This latter trait is of great commercial importance in the mercerization process and gives some information regarding the character of the cuticle. It is known that a decrease through shrinkage occurs when the fibre is first exposed to air and becomes desiccated. This takes place both in length and perimeter. Again in mercerization there is a further reduction in length, but an increase in circumference—the cuticle expanding laterally while contracting longitudinally. On washing and drying the section area is again decreased, length remaining constant, with a corresponding change in the cuticle. Thus the cuticle acts as a semi-elastic retaining membrane conforming to all the changes in the size of the fibre, but not expanding past the predetermined maximum * as set when the hair was growing and in a state of turgor. This remarkable ability of the cuticle tenaciously to follow the anisotropic swellings and contractions of the fibre under its own limiting conditions, without physical evidence of such changes in the nature of creases, lappings, or open ruptures, is one of the strangest (and least understood) properties of cotton.

Calvert and Summers[9] present high-powered microscopic evidence of flat spiralling bands (ridges and depressions which are "notch-like" in profile) and Balls[10] also reports slow-angle spirals in the cuticle. The former authorities offer this structure, plus the assumption that the cuticle has less imbibition power than the cellulose, as a possible explanation of the elastic phenomena. No such structure was observed in this work, possibly due to the unavailability of fresh greenhouse material. It seems likely, however, that the structures so described are really due to the primary wall, especially when its lipoid substances and differentially oriented swelling ellipsoid are considered, and should not be attributed solely to the cuticle.

It has been found to be almost impossible to study the physical characteristics of the cuticle by the usual means. The observations here recorded were obtained by using direct incident light, high-powered dry

* The ratio of collapsed hair-width to final width after mercerization is 1.0/0.8. Washing and drying, however, cause a reduction from the full width attained when the hair is in the hydroxide solution; this ratio is 1.0/1.3. Both can be accepted as standard,[8] for the average of many samples shows but slight variation over all types of cotton.

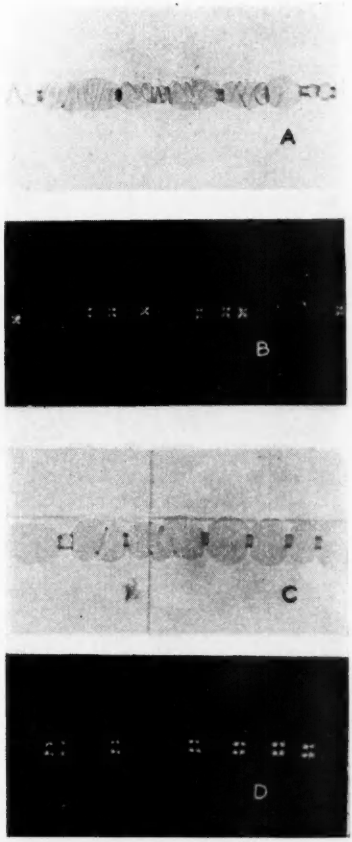

FIG. 2. Four views of single cotton fibres in $Cu(NH_3)_4(OH)_2$. The swelling effect is characteristic. Note the restraining cuticle film in collars and spiral strands. B is the same specimen as A, but between crossed nicols; the polarizing effects under the cuticle membrane are particularly evident.

or oil-immersion objectives, and a special "reflecting bicentric" condenser. With a suitably mounted specimen and the means of study noted the following may be said: The cuticle layer is extremely tightly moulded to the actual wall of the cell. High power reveals its surface as far from smooth; in fact it appears rough and humpy, frequently criss-crossed by sub-structure wrinkles. Occasionally a spiral pattern, similar to that of the wall structure, is observed for short distances as though embossed onto the cuticle film, and more rarely a wide, deep, and heavy striation as illustrated by Lawrie.[11] The most pronounced of these were resolvable at other than oil immersion powers into distinct "hill and valley" profiles when brought into suitable position by the capillary rotator. No method of ascertaining the relation of the waxes and oil to the cuticle was discovered.

The cuticle, of course, is susceptible to various means of destruction or damage. A staining technique based on this and showing the absence, rather than the presence, of the cuticle may well be mentioned here. This is the Congo Red test of Bright [12] initiated for the purpose of detecting the damage done to cotton fibres. Thus any accident (mechanical, bacterial, etc.) which results in the abrasion, removal or penetration of the cuticle can be clearly shown by this process in which the exposed cellulose is stained red while that still protected by the cuticle is untouched. (Two examples of this are given in Fig. 3.) A further discussion of a more natural cracking or fissuring will be included under the heading "Irregularities."

Except for actual fissure breaks or openings the cuticle appears unbroken in its spread over such fibre defects and irregularities as "pits," slip planes, etc. Several attempts were made to see if the formations named after DeMosenthal actually pierced through the cuticle. Staining by Bright's method gave only negative results, as did any attempts to obtain cast impressions.[5] The latter failure, however, may be more due to the extreme smallness of the diameter of the fault, which resists the influx of the moulding medium, and, should impressions be recorded as they were in the case of strain-caused fissures, it would not necessarily mean a punctured cuticle, but rather an elastic and tenacious one. Nevertheless, the microscopic evidence points to but few cuticle breaks and these over the grossest of the fibre faults.

Primary Wall

The major constituent of the lengthwise-growing hair is the primary wall. In this stage the fibre assumes the shape of a long, thin-walled, hollow-tube closed at the apex. With normal commercial fibres this wall is extremely hard to detect, as it forms but a small portion (approximately 9%) of the average fibre. Although it is possible to observe it as a thin outer layer in cross-section, the best means of studying this wall is from fibres taken from bolls before the 21st day after flowering; or from selected hairs in commercial samples which, due to some functional disorder during development, did not receive a secondary deposit of thickening cellulose.* Such fibres assume the shape of a flat, thin-walled, slightly irregular ribbon, crumpled and creased in appearance due to differential shrinkage and

* These, common in greater or less degree to all cottons, are generally termed "dead" fibres. A more correct term would be "immature"; all cotton fibres in reality being dead shortly after boll opening.

devoid of the usual convolution twist. Here architectural detail, both internal and external, can be ascribed solely to the primary wall, as secondary thickening is known to be missing.

Evidence of this layer is also given when a fibre is treated in suitable solutions of $Cu(NH_3)_4(OH)_2$ or critical H_2SO_4. This treatment results in a quicker swelling of the primary wall which separates from the body of the fibre and lies slightly away from, though more or less parallel to, the specimen. Shortly afterwards the secondary wall reacts to the chemical stimulus,

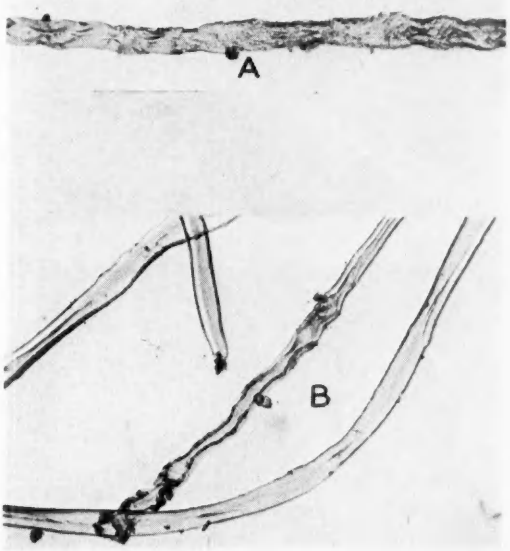

FIG. 3. Maltreated cotton fibres treated with NaOH and Congo Red to show otherwise undistinguishable damage. A is a photomicrograph of a hair suffering from severe bacteriological attack. B illustrates mechanical abuse; a ruptured hair, and one with crushed and pierced side walls, besides two comparatively undamaged fibres are included.

swelling and overtaking the primary wall so that continued reaction proceeds again on an apparently unit structure. This differential period is extremely short (approximately 30 seconds) but the separation is sufficiently evident in Fig. 4 to be clear.

Such a differential reaction is probably but another proof of the chemical difference existing between the cellulose composition of the two walls. Support of this contention, which is generally accepted, rests upon the following: Balls [4] reports that fibres with little or no secondary thickening

react differently to dyestuffs.* Kaczkowski and Feferman's [13] experiments show that normal cottons exhibit two distinct reactions towards alkalis, indicating components of varying composition. Furthermore, Denham [29] states there is evidence to prove a profound change in the chemical com-

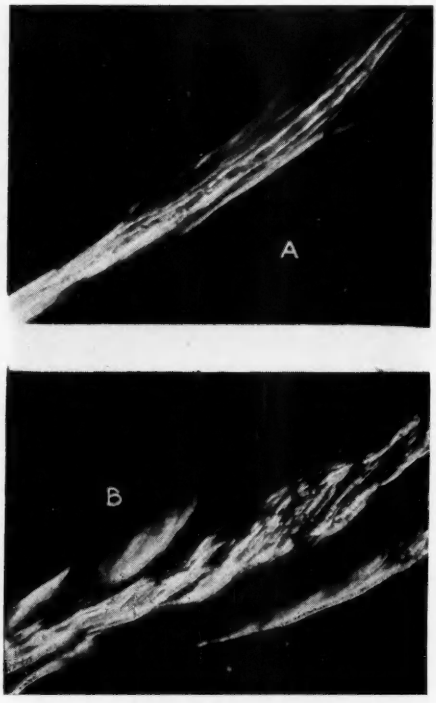

FIG. 4. The momentary differentiation of primary and secondary walls in swelling media. B particularly shows this difference—the primary wall is fully expanded and tends towards solution; the secondary wall lags behind (its fibrillal structure easily visible). Part of this action is due to the accessibility of the outer hair wall to the reagent, but part is also due to their chemical dissimilarity.

position of the cell sap at the time when elongation in length ceases and secondary growth begins. And finally Priestly,[15] independently of Balls, has shown that the primary wall or "pre-cellulose," even when adult, is not the same as ordinary cellulose.

* This is taken to be chemical action; not visual differences due to optical phenomena.

Structural detail in the wall is hard to discern. Development treatments with KOH and pressure, however, will permit, on careful inspection, the recording of spiral lines. These are at approximately the same angle as those readily observable in the secondary layer (namely, 25 degrees) and are positively not due to secondary growth. Occasionally, places in the same specimen were found showing both Z and S helicies, but a definite reversal point was not seen. Nor was the existence of both hands of spirals in the same place confirmed. Stained lateral sections [6] of primary wall were also made, teased out to lie flat, and securely mounted. Aside from eliminating the tendency to error through focusing on both sides of the thin ribbon at the same time, little advantage was noted and there was no evidence of the slow-reversing spirals reported by Balls.[16] This is interesting, for, although these latter undoubtedly do exist, those actually discovered as similar to the secondary fibrils have, as far as can be ascertained, never before been reported. Their definite conformation by independent rechecking is still lacking, but the hazard of optical illusion or artifact causation was considered and tested for in various manners.

Balls' co-existing reversing spirals are of a different type, although of as difficult a nature to determine. They occur at 70° angles to the hair axis, are closely set, and of delicate nature and fine markings. Their reaction in elliptically polarized light led to the deduction that the optic axes were orientated more or less perpendicularly to the plane of the wall.[18]

In contradiction to the reaction ascribed to the cuticle, as described in the previous section, it is well to point out the part the primary wall plays in bast fibres, such as hemp. Here, in the absence of a cuticle, a similar beading action is observed when the fibre is treated with suitable swelling agents. This is due to the differential rate of swelling between primary and secondary wall in their reaction with the chemical reagent. In the case of hemp this is ascribed to the lignification of the primary wall,[17] a condition not encountered in cotton. However, the evidence of chemical difference and structural make-up is strong enough to warrant the consideration that the primary wall may have an influence on this characteristic "rosary" effect not previously associated with it, but connected solely to the cuticle.

Finally, it is interesting to note that although this wall is a "polarizing structure" it is not yet definitely proven to be of micellar composition. Other evidence, however, especially that of swelling and in polarized light, allows the assumption to be fairly made. This despite the fact that the primary wall per unit weight is decidedly weaker than the secondary Experiments [4] have shown, in fact, that the average break per .001 mg. of hair weight per cm. was 2 grams for the primary wall and 5 grams for the secondary, an average increase in strength per growth ring of 0.1 grams. This is not without interest when it is recalled that the main constituent of neps is the primary wall.

Secondary Wall

The secondary wall is the major constituent of the normal cotton hair. It is built by a process described later, during the last half of the boll's closed existence; a period of approximately 27 days (21st-48th). During each of these days a new and separable layer of cellulose is laid down, in a manner analogous to the growth rings of a tree, except that each of these

cotton "growth-rings," "layers," or "concentric shells," is declared to be the product of one night's effort, and they proceed from the outside towards the centre. As noted before, this secondary thickening differs chemically from the primary wall or "pre-cellulose," while it is also interesting to note that the density of the fibre as a whole is closer to .90–1.00 than the 1.50–1.55 usually ascribed to pure cellulose.

Secondary growth, although in the form of concentric layers, does not assume the plain surface structure of closely fitting tubes like a closed telescope. Rather the helically spiralling formations, already mentioned in regard to the primary wall and cuticle, are even more prominently pronounced here. To the conception of layer growth, then, must be added the idea that each layer consists of a series of spirally-inclining, minute fibrils which frequently and at irregular points change the direction of their inclination from S to Z and vice versa along the course of the hair's length.

This spiral structure in the secondary wall is easily shown, according to the treatment previously discussed.[5] The very slightest pressure, after immersion in acid or alkali, being sufficient to form bands of spiral fibrillae in some part of the hair, while, occasionally, untreated specimens are found showing a clear and distinct spiral structure. Careful measurements on as normal specimens as possible give average values of inclination between fibrils and fibre axis of 24° Z and S. This changes and is reduced slightly as the centre of the hair is reached.

The spiral fibrillae are discrete units, and, although they are tightly packed together and closely parallel, occasionally a space or crevice will form between two of them. Careful correlation has shown these extra wide crevices or "pit" spirals to be similar to those discovered in green material by Balls,[2] and described by him as follows:

> "Meanwhile, by the thirty-third day it is easy to distinguish the simple pits in the wall. These pits are common in many kinds of vegetable cell-wall, and are not in any way peculiar to cotton. They are of about the same length as the diameter of the cell, and are set at an angle of about 30 degrees to the axis of the hair.
>
> "They are not at all easy to recognize; ordinary illumination with a good microscope does not display them, owing to the translucency of the cell wall and the background of granular protoplasm. It should also be noticed that they cannot be seen in ripe hairs, having been obliterated by the twist, nor are they distinct in old pickled material; but they cannot be missed in the unripe, untwisted hairs, given a good microscope, new material, and correct illumination."

Similar structure is encountered in other vegetable material and is not unique with cotton. Thus the wall of the hair may be considered as consisting of multiple layers of cellulose each made up of several hundred fibrils following an irregular spiral pattern.

Balls has reported a considerable degree of regularity in wall configuration, but this has not been confirmed in the present study.* In fact, in one fibre it is often possible to observe a good many different arrangements and patternings of the parts. Thus the slope of the spirals, their mutual angle, and the distance between individual fibrils all vary in several different ways along the length of a single hair. Moreover, as far as can

* "The difference in type of cotton, Egyptian vs Upland, may be a sufficient explanation to account for this. In any case although confirmation is lacking, the evidence is not necessarily conflicting."

be observed when the fibre is being treated to reveal its internal structure, the strict radial patterning advanced by Balls does not seem to be adhered to as strictly as he states; but of this more will be said later. No evidence of a double spiral effect, that could definitely be said to exist in but one wall layer of the specimen, was seen; * although this conflicting spirality effect was often observed when the two walls of the fibre were closely apressed, despite the precautions taken to guard against this error.

A further point of interest is the existence, at opposite ends of the sectioned-hair's major axis, of periodically occurring spirals that follow the general path of the fibrils, but are of seemingly different chemical and physical composition. This is evidenced by a differential (deeper) staining in naphthamine blue and an extra wide and deep opening or furrow; both may be caused by the higher stress occurring in the hair at this point after collapse. It has been suggested[14] that these "weak points" may have a considerable effect on convolution determination; of which more will be said later.

The question of showing both the growth ring and spiral fibrillae structure at the same time in one specimen presents many difficulties. Possibly the best answer is given by longitudinal mounts, where reagents such as $Cu(NH_3)_4(OH)_2$ can clearly show the lines of growth (see Fig. 5) as many parallel lamella on either side of the lumen; while pressure in the less affected parts of the specimen will reveal the spiral structure. Optical, longitudinal sections of cotton in 18% NaOH will also show these growth lines, and, if the specimen can be oriented correctly, growth rings by optical cross-sectioning can be seen.

It appears to be impossible, however, to show both radial and tangential growth boundaries at the same time in cross-sections, although either alone can be clearly shown if the treatment and reagent are suitably chosen. Such aspects as cohesion, surface tension, and molecular bonding, moreover, make it doubtful if both these sets of structures will ever appear at the same time. Certainly the phenomena reported by Balls,[18] similar to the work of Griffith[19] (with quartz rods), throws light in this direction. He states that the spirals produced in a hair by pressure alone, will, when tensioned, remain evident until the point of rupture is reached, after which they suddenly disappear almost completely. This has been confirmed in the present work and would seemingly indicate a molecular disturbance produced only under the rebounding impact of a tensioned break. Undoubtedly a similar condition could easily be realised by the shock of the impact in razor sectioning.

In untreated cross-sections of cotton fibres, the "growth rings" are too fine and too closely packed to be resolved even with the highest numerical aperture and magnifying power.† The method found most efficient in revealing them is to so swell the section that its component parts increase and separate sufficiently to be seen. This consists of treating the specimens with critical strength H_2SO_4 or $Cu(NH_3)_4(OH)_2$; (and as each hair is distinctly individual, after the approximately correct strength of the solution is obtained, it is better to hold this constant and consider the specimen as the variable.)

* It is, however, possible to see this double spiral effect in the primary wall alone.

† An untreated cross-section of a "fuzz" hair, showing a few ill defined growth layers, has been observed.

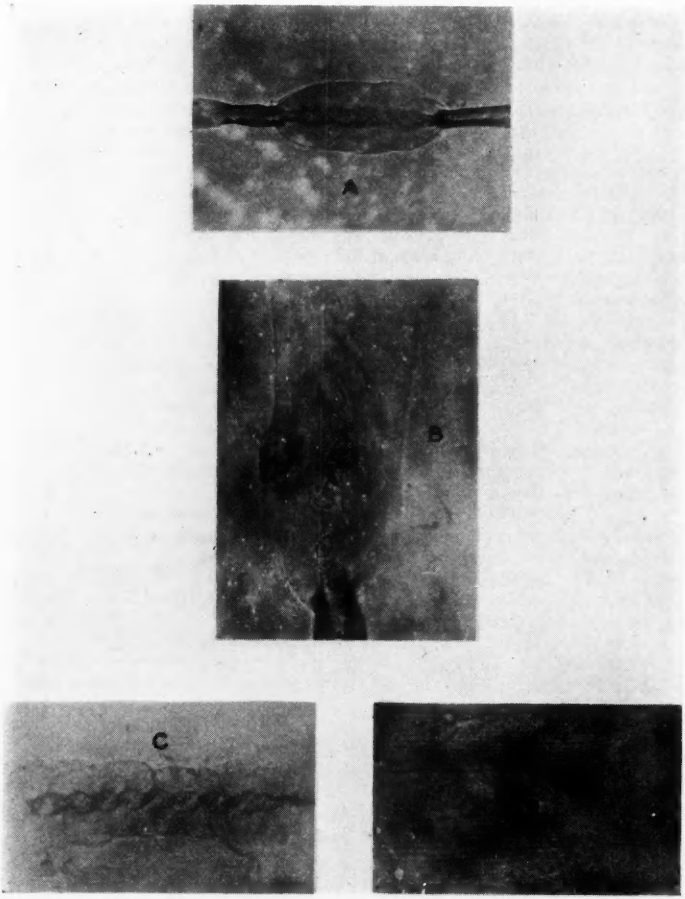

FIG. 5. Cotton hairs in swelling media: A and C in $Cu(NH_3)_4(OH)_2$; B and D in H_2SO_4. All show the boundaries of the daily deposit in the secondary wall or growth lamellae (and also the swollen protoplasm). A, in addition, shows helical patterning and portions of but slightly swollen cell walls.

It has been known for some time that the characteristically distinct attribute of fuzz hairs or "linters," in contra-distinction to the "staple" or commercial fibre, lies in length and diameter measurements. Thus fuzz hairs are greatly restricted in length growth, while normal cotton attains but a small diameter. Actual measurements show the fuzz to be 30 or more times shorter, and two to three times broader, than the staple fibre. Furthermore, breadth growth in the linters proceeds at a quicker pace, until the lumen is almost choked, and, therefore, the growth rings are fewer, larger, and more easily seen. Specimens of Upland Cotton * treated in longitudinal section for both lint and fuzz show 13 to 17 lamellae in each side of the lumen for the former, and 3 to 7 for the latter. As shown in Fig. 6 the physical difference between the two is readily apparent.

The inclination and change of direction of the spiral fibrillae is perhaps the most interesting and significant property of the secondary wall. The cause of the varied patterning which these fibrils follow throughout is not definitely known, though careful researches by Balls [16] appear to show that this intricate system of patterning (observable also in primary wall and cuticle) is predetermined during the outward extension of the sprouting hair, and is somewhat influenced by the factors of final hair length and total time of length extension. As the optic axis is coincident with the fibril axis at all parts of the reversing spiral, the cause of the reversals is not molecular structure but physiological. Nor can it be ascribed to growth cessations (as occur in the afternoons of most cotton producing countries) for constant illumination fails to change the number or frequency of the reversals. And finally, genetic and ordinary environmental conditions have no seeming affect on this quality. The actual cause, therefore, must await the result of further research; the effect of these fibrillar patterns, however, in determining a cotton characteristic important to all users, namely convolutions, is discussed in the next section.

Convolutions

The practical importance of these spirals is that they determine the position, direction, and number of the easily visible and characteristic convolutions. In fact, it has been found [18] that there is a perfect positive correlation between the two under certain conditions. These are that there is no mechanical interference to prevent hair movement on drying, and that the spiral reversal points are not so close together as to physically prevent convolution formation. Of course the hair cells on boll opening are fully thickened but still in straight cylindrical form—without any apparent twisting. Convolutions do not occur even when the inner tension is released by plasmolysis, but only on the death of the protoplasm and the removal of the water of construction.

The collapse of the wall is predetermined in the growth of the hair, and the collapse into band form is generally conceded to precede convolution formation. Denham [14] reports that the determining points of collapse are the "weakness belts" which occur diametrically opposite each other on the cells' long axis; but this in itself is not a sufficient explanation for all convolution formation.

The chief cause probably lies in the drying out of the walls,—which is a particularly interesting phenomenon. The hair wall composition being

* 1-inch staple Wake County, N. C., summer of 1930.

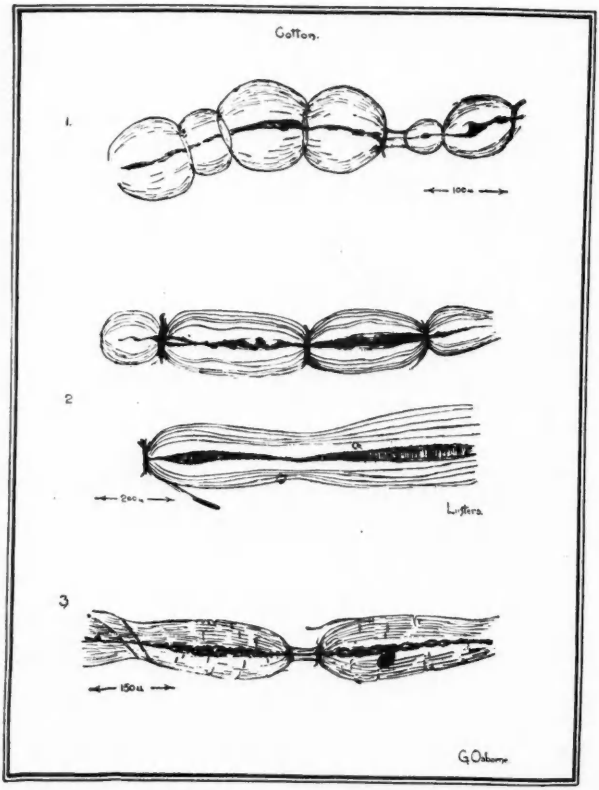

FIG. 6. Camera-lucida drawing showing the effect of ammoniacal copper hydroxide upon the cotton fibre. This is the best means of portraying the deposit zones or growth rings of the secondary cellulose. The difference in this respect between the fuzz hairs (linters) and the staple cotton is evident; secondary growth deposits in the former being fewer, grosser and more pronounced, thus aiding the attainment of large cell diameter and reduced lumen space. The swollen protoplasm is well illustrated in each figure, while open fissures and shredded cuticle are pronounced at 3.

heterogeneous has its weaker structure normal to the length of the fibrils. This is in some way connected to the dessication of the hair on exposure to air, and when the latter takes place a greater shrinkage occurs in a direction perpendicular to the fibrils than parallel with them. As the fibrils spiral in the wall, collapse and shrinkage cause them to form mutual angles with each other and the hair axis and a twisting movement is produced. (See Steinbruick's experiments.[20]) The water loss involved appears to be irreversible. Regardless of distention by osmotic pressure, and the illusory effect produced by strong caustic alkali, the fibre cannot be treated back into the true cylindrical form.

Actually in the boll, where as many as 100,000 one-inch fibres may be crowded into a space of only approximately 1.0 + cubic inch, each fibre exerts a certain influence on the convolutions and twisting-up of the others, and breaks down the perfect correlation between spiral reversals and convolutions measured in unimpeded hairs. Examination of an opened boll, however, where the growing fibres assume a sinuous or cheveleure formation, shows that any mutual interference would be entirely random; so that the relationship largely holds.

Convolutions following directly the order of the spiral fibrillae are of various lengths, ranging from 10 μ to 12700 μ. They are, of course, of alternate hand for different irregular distances. The shape of the convolution is somewhat influenced by genetic and environmental conditions, and the slope depends in part on the ratio of cell wall thickness to ribbon width. It is also worth noting that the great majority (94%) of all hairs start sprouting from the seed coat with a sinister spiral.* As the hair grows apically this may be followed by either a further length of S spiral or a Z spiral. At sometime, and generally frequently, the average ranging from 150 to 250 per inch, a reversal will occur; but the mean of the S as compared to Z spirals, and the length they occupy, will be approximately the same for any one fibre type.

Some workers have divided the convolutions into four groups or classes, but these included formations due to abnormal growth in addition to others having no connection with the fibrillar structure. Denham [14] reports the following classes: (1) fixed, (2) movable, (3) preformed, (4) suppressed. The first is the type directly connected with the actual reversal points, and is hardly affected by the influence of humidity, merely changing slightly as to pitch and position due to fibre swelling and the couples produced by the uncoiling of those convolutions belonging in group two. These latter can be readily watched when an unsecured hair is moistened. Convolutions appear to run along the fibre axis until they meet and neutralize themselves at a reversal point. They are of practical interest, for cotton manufactured under conditions of high humidity should tend to have fewer convolutions per fibre than a similar type processed dry. They both appear to be dependent on the major factors of the ratio of ribbon width to wall thickness, and the sum of the spirals in the wall layers. Preformed convolutions are those caused by the confining limits of boll space during growth, and usually consist of the bends formed by partial or complete buckling or overlapping. Suppressed convolutions, giving the hair the appearance of a fluted rod, occur generally in fibres of circular cross-section, and have little or no effect on its clinging properties.

* Further observations by the same investigators [10] have revealed the phenomena that the Z portions of the fibre are more sturdy and retain their cylindrical shape longer than the more readily collapsed S portions.

Finally, a view presented by Urquhart[21] is of interest concerning all convolution formation. He suggests that as the original deposit of cellulose in the fibre is made in the presence of water, the hydroxyl groups will have water molecules attached to them. That, on the loss of this water, there will be a tendency for the cellulose units to re-orientate themselves in order that the residual valences of the hydroxyl groups may become mutually satisfied. In addition to this rearrangement there may be an actual deformation produced, for the micelles themselves, in an effort to bring the free hydroxyl groups nearer to each other, tend to become disfigured, and this may explain the convolutions of the desiccated hairs.

Lumen

In the young hair the lumen or central channel is the seat of the growing forces. Here the protoplasm, with the nucleus near the tip, and the centre of the canal occupied by vacuoles containing cell sap, keep the long thin tube extended and in a condition of turgor. As secondary growth proceeds the lumen size is decreased; until in normal hairs it is but from 4 to 8% of the total section area (there are, however, wide variations from this). When the hair dies, the desiccated remains of the protoplasm are left in the lumen, and, according to Denham,[22] are particularly conducive to invasion by micro-organisms, although confirmation of this is still lacking.[23] What is known, however, is that these dry remains are particularly liable to erroneous microscopical interpretation as to being integral parts of the cell's structure.

Lateral sections and direct incident lighting show the inside of the canal to be far from the smooth surface described during growth. Thus radial as well as minute concentric cracks and a rough wall surface are clearly evident. Furthermore, open irregular fissures are observed branching from the walls, and extending into the secondary thickening, in exactly the same manner as reported for ramie.[1] This condition may, in part, be due to the contraction on drying, the twisting experienced on convolution formation, and to the strains on the inner layers due to the state of compression existing in heavily thickened hairs.[24] There seems to be no direct connection between this irregular cracking and the pit spirals existing between the fibrils.

The tips of the fibres, particularly in fine strains, are practically devoid of lumen (and also convolutions). These may be of many different forms and shapes, but in normal hairs they tend to be bluntly pointed. At no point along the lumen could a concentric layer of dried protoplasm be seen encircling the innermost secondary layer or appearing as an integral part of it.

Irregularities

It has been decided to group all structural phenomena, other than that due directly to growth, in one section and treat them under the heading "irregularities." This section will, therefore, include a discussion of the following: (1) fissures or slip planes; (2) corrugations; (3) pits; (4) pores; (5) abnormalities.

Fissures.—The photomicrographs of Fig. 7 show excellent examples of cracks or fissure openings in the wall of the cotton fibre. These are to

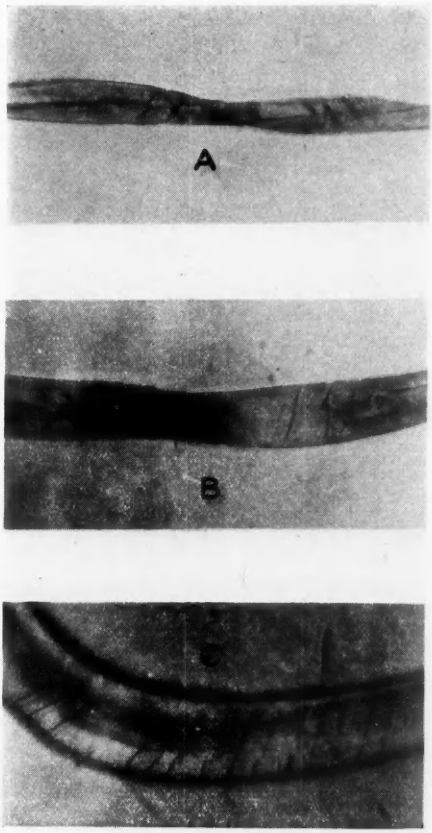

FIG. 7. Three views of induced trans-fibre fissures. Note the change of fissure inclination in A and B—the helix direction of the spiro-fibrillae reverses in the central portion of each of these specimens. C on first inspection exhibited a total absence of cell-wall breaks or imperfections; less than a dozen flexings over a small-diametered glass rod produced the "cracks" shown.

all intents and purposes similar to a like phenomenon first reported by the author [5] in bast fibres. They are best observed in the fibre with plane polarized light where just sufficient color is produced by the varying thickness of the specimen itself to show them in excellent contrast. They occur to some extent in all fibres, but increase with increases in mechanical dam-

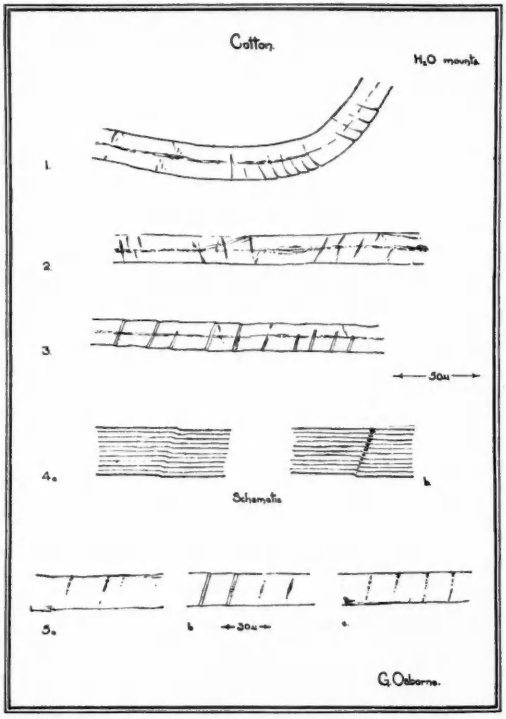

FIG. 8. Illustrations of typical imperfections commonly found in the wall of the cotton fibre. 1 and 2 show trans-fibre fissures—profile and plan view. 3 illustrates fibre corrugations. 4 and 5 illustrate possible stages in the development of corrugations, pits and fissures.

age or abuse. Thus studies of a batch of cotton, through severe opening, picking and carding, showed progressive increases in fissuring. Such defects can be readily induced, Fig. 7B being from a fibre which had been shaken for four hours in an Erlenmeyer flask containing 5 doz., 4 mm. glass balls. Again, as the time of agitation was prolonged, the fissuring increased.

It is hard to see these fissures as penetrating openings. The fibre must be correctly orientated and the open crevice must be parallel to the direction of inspection. By use of the capillary rotator, especially when using polarized light and selenite plates, such positive openings (penetrating in some cases almost to the lumen) were clearly seen. Casting technique,[5] although fairly difficult due to the convolutions, also definitely established these open fissures. Fig. 8, which is a camera-lucida drawing of a cotton specimen to scale, shows the condition and appearance of these fissures when aligned to show their openings. Fig. 8 also shows their appearance in the normal or direct (as distinct from the profile) position. This, together with photomicrograph of Fig. 7, shows these fissures to be similar to the slip planes in cotton reported by Balls.[4] Of further interest, shown in both Figs. 7 and 9, is the direction of inclination of the fissures. Thus each set lies at approximately right angles to the length direction of the spiral fibrillae or pit spirals. (The significance of this will be discussed later.) Checking the direction of inclination of the fibrils is easily done by crossing the nicol prisms, and this relationship of approximate perpendicular arrangement in regard to pitch, reversal and direction, as in bast cells, appears (although stated[10] to differ infrequently) to be constant. Such imperfections are particularly likely to form where the hair is either naturally or artificially curved or bent; and it is possible to produce them experimentally on a slide under the microscope by employing this feature. Their main interest to practical users is that their occurrence is responsible for a decrease in the mechanical strength of the fibre and that they also are potential places for chemical and bacteriological attack.

CORRUGATIONS.—Cases of corrugations or bucklings have also been noticed, especially in thin-walled fibres, and, although they are believed to be but a modification of the regular fissure openings, they deserve mention by themselves and in connection with the much debated structure reported by DeMosenthal.[25]

Their form, as illustrated by Fig. 8, assumes the characteristics of a series of angular pleats, with bent right-angular projecting ends or "overhangs." The degree and direction of inclination are not fixed, nor is there a close correlation similar to that existing between the perpendicular relationship of fibrils and fissure angle. Following one of these pleats around the periphery of the fibre, by means of the rotator, shows it rarely to exceed one-half the circumference, while there is a decided tendency for these faults to cover but one-quarter of the spread fibre width, and to cluster along but one (the compressed) side. They do not appear to be either increased or decreased by mechanical agitationary treatment and are fewer in number than the more regular slip-plane fissures. However, chemical disintegration, as in 60% H_2SO_4, often appears to start its attack along these lines, which soon develop into cleavage planes and completely open. It may be suggested that they are caused in growth, where the confining space of the boll sets up a resistance to the extending hair, forcing it to lap-back for small distances upon itself, thus producing the characteristic pleat or buckle.

(To be continued)

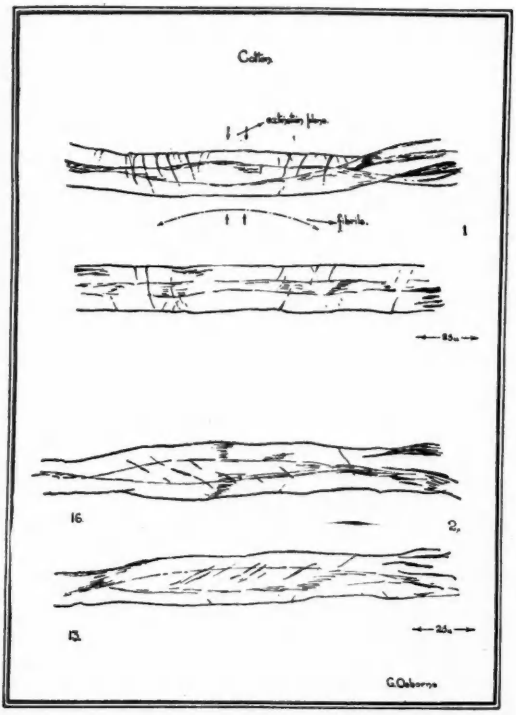

FIG. 9. 1 (a camera-lucida drawing) is taken from a typical cotton fibre and shows the relationship of trans-fibre fissures to fibril patterning. The directional course of the fibrils is represented by the dotted arc (determined between crossed nicols), the angle of fissure inclination changing on either side of the extinction plane (where fibril and fibre axis are parallel) so as to maintain a constant relationship tending towards 90°.

2 shows the same phenomena, and in addition illustrates the changes experienced by focusing on different parts of an unchanged specimen. Thus at 16 the upper surface of a single hair is in sharp focus; at 13 an objective lowering of 7.5μ, the bottom side of the fibre is in view. Fissure-fibril relationship, however, although appearing reversed, is constant.

References

1. Osborne, G. G. Micro-Analysis of Textile Fibres, Part II. *Tex. Rsch., V*, 75–91 (1934).
2. Balls, W. L. The Development and Properties of Raw Cotton. London, 1915.
3. Denham, H. J. *J. T. I., 13*, 99–112 (1922).
4. Balls, W. L. Studies of Quality in Cotton. London, 1928.
5. Osborne, G. G. *Tex. Rsch., 4*, 84–111 (1933).
6. Farr, W. K. *Contrib. Boyce Thompson Inst., 3*, 441–458 (1931).
7. Sieber, W. and Kusenbauck, K. *Int. Cotton Bull., 11*, 710 (1933).
8. Clegg, G. G. and Harland, S. G. *J. T. I., 15*, T14–26 (1924).
9. Calvert, M. A. and Summers, F. *Shirley Inst. Mem., 4*, 49–84 (1925).
10. Balls, W. L. and Hancock, H. A. *Proc. Royal Soc., B99*, 130–147.
11. Laurie, L. G. *J. T. I., 20*, P102 (1929).
12. Bright, T. B. *J. T. I., 17*, T396–404 (1926).
13. Kaczkowski, W. et al. *Przenysl. Chem., 11*, 205–208 (1927).
14. Denham, H. J. *J. T. I., 14*, T86–116 (1923).
15. Priestley, J. H. *New Phytologist, 21*, 4 (1922).
16. Balls, W. L. *Proc. Royal Soc., B95*, 72–89 (1923).
17. Van Iterson, G. *Chem. Weekblad, 24*, 15 (1927).
18. Balls, W. L. and Hancock, H. A. *Proc. Royal Soc., B93*, 426–440 (1922).
19. Griffith, A. A. *Phil. Trans. Roy. Soc., A221*, 163–198 (1920).
20. Steinbrunck, C. *Biol. Zentr., 26*, 657–744 (1906).
21. Urquhart, A. R. *J. T. I., 20*, T125–130 (1929).
22. Denham, H. J. *J. T. I., 13*, 240–248 (1922).
23. Prindle, B. Private comm., M. I. T., 1934.
24. Balls, W. L. *J. T. I., 22*, P57 (1931).
25. DeMosenthal, C. H. *J. Soc. Chem., 26*, 444 (1907).

Obituary

Alfred L. Lustig, president and general manager of the Apponaug (R. I.) Company, and a charter member and director of U. S. Institute for Textile Research, Inc., died March 19th, at Winter Park, Fla., where he had been since January. He had never fully recovered from a serious illness suffered four years ago. He was born in Vienna, Austria, 70 years ago, and received there his training as a chemist, coming to this country at an early age. Long before he became head of the Apponaug Company in 1914 he had established an enviable reputation as a printer of fine cotton goods. Among the plants with which he had been connected were the old Lexington Print Works, Acme Finishing Co., Merrimack Mfg. Co., and the Cranston and Glenlyon print works. He is survived by his widow and four daughters.

Abstracts

This section is compiled under the direction of the Committee on Abstracts and Bibliography: Prof. E. R. Schwarz, Chairman, Dr. W. E. Emley, Prof. Louis A. Olney and M. W. Weiss.

I. Fibres (Synthetic and Natural) and Fibre Analysis

Alpha Cellulose from Aspen Trees. Anon. *Sci., Supplement* 1934, V. 80, P. 6.

As a result of research at the University of Minnesota, a process has been announced for obtaining alpha cellulose, for use in cellophane, rayon and lacquers, from the aspen tree, also known as the "poplar" which abounds in the cutover lands of northern Minnesota. It is proposed to establish a small plant to turn out perhaps 500 pounds of the material so that cost of production may be precisely determined. It is stated that one cord of aspen produces 1600 pounds of alpha cellulose. The material turned out by this process has a purity comparable to the best now on the market according to Dr. Reyerson. The process also makes it possible to control the viscosity of the product, so that alpha cellulose with high viscosity suitable for use in rayon manufacture can be obtained as well as low viscosity material for use in lacquers. (S)

Chemical and Molecular Structure of Textile Fibres. P. Krais. *Monatschr. Textil-Ind.*, 1934, V. 49, P. 205–6.

A review of modern views of the chem. and mol. structure of cotton, wool, silk and rayon. (Copied complete from *Chem. Abs.*, 1935, V. 29, Col. 348.) (W)

Chlorinated Wool: Some Properties of. Determination of Damage in Chlorinated Knitted Woolen Goods. S. R. Trotman, H. S. Bell and H. Saunderson. *Am. Dye. Rptr.*, 1934, V. 23, P. 533–4, 543–7.

This is a reprint from the *J. Soc. Chem. Ind.* The author points out that microscopical examination of the fibre to show partial or complete absence of scales is faulty because the destruction of the scales is probably the final effect of over-chlorination and is preceded by modification of the proteins of the cortex which may be a serious matter. The use of various chemical methods for bringing out this damage is indicated and a series of tabulated results of treatment with various dyes is given. (S)

Felting: Latest Explanation of. Anon. *Am. Dye. Rptr.*, 1934, V. 23, P. 448.

This is a brief note which is an outline of a contribution by A. T. King of the British Wool Industries Research Association. The detailed refer-

ence is to be found in *Chem. and Ind.*, V. 53, P. 339. It has been reported in connection with this work that the application of a simple and inexpensive treatment during processing will cut down the time required for fulling by as much as one half in certain cases. It is further noted that this machine may possibly be made to exert both stretching and compressing forces on the goods during fulling by means of a pair of rollers at the spout of the fulling mill, driven in the opposite direction to the movement of the cloth. (S)

FIBRES OF HEMP AND LINEN: DIFFERENTIATION BETWEEN. F. Janák. *Chem. Listy*, 1933, V. 27, P. 388–92; *Chem. Abs.*, 1934, V. 28, Col. 7543. (W)

FIBROIN: REGENERATION OF. I. VISCOSITY OF FIBROIN SOL. T. Tanizaki. *J. Agr. Chem. Soc. Japan*, 1934, V. 10, P. 750–3.

When the difference between the viscosity of fibroin sol and that of the dispersion medium was larger, the film formation of the regenerated fibroin was comparatively easier. (Copied complete from *Chem. Abs.*, 1934, V. 28, Col. 7543.) (W)

FLAX FIBRE STRUCTURE AND QUALITY. XIII. S. A. G. Caldwell. *Tex. Mfr.*, 1934, V. 60, P. 222; *Chem. Abs.*, 1935, V. 29, Col. 348. (W)

FLOW OF VISCOSE IN PIPES: ON THE. (German.) A. Pakschwer and M. Bunin. *Die Kunstseide*, 1934, V. 16, P. 28–42.

The authors point out that research on the flow of viscose in pipes is not only of theoretical interest but also has considerable practical value. They note the fact that the conditions of flow in the pipe line leading to the pump have a considerable influence on the pressures and steadiness with which the pumps may be operated and also have a decided effect upon the extrusion of the filament from the spinnerets. The differences between the flow of a fluid, such as the so-called perfect fluids which have been discussed by Newton, Reynolds, etc., are pointed out. The article proceeds to develop empirical equations for computing the flow based on work by several authors whose efforts in this direction are briefly reviewed. Several diagrams and tables serve to clarify the material and a number of references are included at the end of the article. (S)

HISTAMINE: EXAMINATION OF COTTON, COIR AND ESPARTO-GRASS DUST FOR. A. D. Macdonald and H. B. Maitland. *J. Hyg.*, 1934, V. 34, P. 317–21.

Histamine is present in most particles of cotton dust, especially the smaller ones which are apt to reach the lungs. Histamine was not found in coir or esparto-grass dust and workers exposed to these dusts do not have the lung troubles found among cotton workers. (Copied complete from *Chem. Abs.*, 1935, V. 29, Col. 348.) (W)

IODINE NUMBER OF WOOL. R. W. McKay. *Am. Dye. Rptr.*, 1934, V. 23, P. 697–8.

This work forms part of an investigation of the reactions of chlorine and related substances on wool in producing an unshrinkable finish. The "iodine numbers" reported by Harris, Neville and Fritz are approximately

confirmed, but it is shown that the stoiciometrical relations found by these authors between iodine number and free amino nitrogen are of an accidental nature. If this method is used as an index of the progress of reaction of various chemicals on wool the empirical nature of these "iodine numbers" should be recognized. (S)

II. Yarns and Fabrics

Absorption of Water by Fabrics: Determination of. Katharine Hess and Dorothy Reidheimer. *Am. Dye. Rptr.*, 1934, V. 23, P. 715–6, 743.

It is to be regretted that a typographical error in the title of this article makes the title read "wear" instead of "water." The article describes briefly tests made by several methods for the determination of the rate of moisture absorption by various types of textile materials and recommends several satisfactory procedures, particularly one for knit goods. (S)

Chemical Conditioning Found Superior to Atmospheric in Recent Tests on Cotton Filling. Robert L. Evans. *Tex. Wld.*, 1934, V. 84, P. 92.

A very brief outline giving the results in the form of a table on tests by chemical conditioning and atmospheric conditioning on some 24 boxes of 200 bobbins each. The yarn samples were taken after varying periods of conditioning by several methods and the outer, middle and inner layers of each bobbin were kept separate so that the effect of penetration of the bobbin was noted as well as the effect of position of the bobbins in the boxes. It was found that chemical conditioning as practiced in the test gave much more uniform and lasting results, that bobbins on the bottom where moisture was put in chemically gave superior results while bobbins on the bottom of the boxes atmospherically treated were underconditioned. (S)

Cotton and Finish. R. H. Wright. *Tex. Mfr.*, 1934, V. 60, P. 228, 251.

The effect of finish and quality of the fabric upon the appeal of the material are discussed and demonstrated by samples. Methods of cooperation between the fabric manufacturer and the finisher are discussed. (Copied complete from *Chem. Abs.*, 1935, V. 29, Col. 349.) (W)

Damages in Wool: Can the Chemical Analytical Methods of Detecting Be Utilized in the Wool Trade? A. Molnar. *Monatschr. Textil-Ind.*, 1934, V. 49, P. 206–7.

M. describes eight different chem. tests which are of value to the wool trade. (Copied complete from *Chem. Abs.*, 1935, V. 29, Col. 349.) (W)

Cotton Twists. Simple Chart Shows Correct Turns per Inch Almost Instantly. Carl D. Brandt. *Tex. Wld.*, 1934, V. 84, P. 75–6.

This is a continuation of articles appearing in the Feb. 14 and May 1934 issues of *Tex. Wld.* The range of staple lengths has now been extended sufficiently to permit the establishment of general formuli and the curves which accompany the present paper. Consideration must be given to the fact that cotton fibre is very variable in itself and that therefore hard and fast rules concerning its reaction cannot be laid down. Further the spinning process is not perfect and there may be as much as 15% varia-

tion in the amount of twist in different parts of cotton yarn. The present work, however, can be accepted as representing average conditions. This is a further application of the nomographic principle of charting to textile problems. (S)

HOSIERY-TESTING MACHINE: FACTORS AFFECTING THE PERFORMANCE OF HOSIERY ON THE. H. F. Schiefer and R. S. Cleveland. *B. S. J. Rsch.*, Jan. 1935, P. 1–16.

The results which have been obtained on the hosiery-testing machine since the publication of Research Paper RP679 are discussed. It is shown that laundering, dyeing, aging, finishing, and construction all have a great effect on the distensibility, elasticity, and endurability of the stockings on repeated distention. The information given furnishes a necessary background for the use of the machine for hosiery testing, and demonstrates its suitability for researches in knitting, degumming, dyeing, finishing, aging, laundering, redyeing, and refinishing of hosiery. (C)

MOISTURE RELATIONS OF AIRCRAFT FABRICS. Gordon M. Kline. *B. S. J. Rsch.*, Jan. 1935, P. 67–84; *Am. Dye. Rptr.*, 1935, V. 24, P. 4–7.

The amount of moisture held at various relative humidities and the rate of absorption of this moisture have been determined for airplane and balloon cloths, airplane fabric doped with cellulose nitrate, outer-cover fabric doped with cellulose acetate, dope films, and gas-cell fabrics. The fabrics coated with cellulose nitrate dope show a maximum gain in weight in a saturated atmosphere of approximately 12% of their weight when in equilibrium with air at 21° C. and 65% relative humidity. The fabrics coated with cellulose acetate dope behave similarly to the cellulose nitrate products at relative humidities as high as 97%; in a saturated atmosphere they are considerably more hygroscopic. Gas-cell fabric, which consisted of balloon cloth coated with a mixture of gelatin and rubber latex, containing polyglycerol as a plasticizer, is the most hygroscopic of the materials studied. On exposure to a saturated atmosphere lightweight gas-cell fabric takes up in seven days water equivalent to approximately 50% of its weight, and in four weeks it approximately doubles its weight. Paraffin, which is always applied to the gas-cell fabric in service, retards considerably the rate of absorption; thus 14% by weight decreases the absorption of moisture to approximately 30% in one week and 60% in four weeks at 100% relative humidity. The deterioration of the gas-cell fabric by mold attack at high humidities has been found to take place very rapidly; it is recommended that a small amount of a fungicide be incorporated with the "gelatin-latex" coating to prevent this action. (C)

III. CHEMICAL AND OTHER PROCESSING (NOT OTHERWISE CLASSIFIED)

CAUSE OF THE DREADED CARBONIZING SPOTS. Walter Ryczynski. *Z. ges. Textil-Ind.*, 1934, V. 37, P. 323–4.

Carbonizing spots occur frequently in piece carbonized wool and show up after dyeing, especially on blanks. The fact that they occur most frequently on fabrics of finer quality leads one to believe that they are due,

not to faulty carbonizing or dyeing, but to failure to remove fats after the fulling and washing operations. These fatty bodies shrink in the presence of H_2SO_4 at 100° or more and, after dyeing, produce the well-known light spots in the goods, lighter because they are more water- and hence dye-repellant. Carbonizing after dyeing is possible but, in a re-dye, the spots are sure to occur. Extreme care should be exercised in the removal of fulling residues before carbonizing; *e.g.*, wash twice with fuller's earth. In the case of finer qualities, difficult to scour, the wool is carbonized in loose form. (Copied complete from *Chem. Abs.*, 1934, V. 28, Col. 7021.) (W)

CELLULOSE: ABSORPTION OF DIRECT DYES BY. S. M. Neale and W. H. Stringfellow. *Rev. gen. mat. color.*, 1934, V. 38, P. 315–6; *Chem. Abs.*, 1934, V. 28, Col. 2968, 6316. (W)

CELLULOSE ACETATE: NATURE OF THE DYEING PROCESS IN—AND THE HYDROLYTIC CONSTANT OF CHRYSOIDINE G. A. H. Burr and M. S. Burr. *J. Soc. Dyers Col.*, 1934, V. 50, P. 42–7; *Chem. Abs.*, 1934, V. 28, Col. 6316. (W)

CELLULOSE FINISHES ON SILK AND OTHER FABRICS. Arthur Jones. *Dyer*, 1934, V. 72, P. 269–70.

The uses of cellulose lacquers for finishing mourning crepes and crepe de chines, and for producing waterproof finishes for transparent wrapping material, antitarnish finishes for tinsel fabrics and fireproof finishes for theater curtains and cinema screens, are briefly described. (Copied complete from *Chem. Abs.*, 1934, V. 28, Col. 7543.) (W)

CHEMICAL TREATMENTS OF WOOL FIBRE. III. TREATMENTS ANALOGOUS TO HYPOCHLORITE CHLORINATION. H. Sobue and Y. Hirano. *J. Soc. Chem. Ind., Japan* 37, Suppl. binding, 1934, P. 427–30; *Chem. Abs.*, 1934, V. 28, Col. 7028, 7541. (W)

CHLORINE BLEACH. I. THEORY OF THE CHLORINE BLEACH. Eugen Shilov and Vassili Minaev. *Mell. Textilber.*, 1934, V. 15, P. 221–4, 266–9; *Chem. Abs.*, 1934, V. 28, Col. 7029. (W)

COTTON BLEACHING: REVIEW OF. W. Kershaw and F. L. Barrett. *J. Soc. Dyers Col., Jubilee Issue* 1884–1934, P. 90–8; *Chem. Abs.*, 1934, V. 28, Col. 6314. (W)

DRY CLEANING, WET CLEANING AND DYEING. F. W. Walker. *J. Soc. Dyers Col., Jubilee Issue* 1884–1934, P. 190–202; *Chem. Abs.*, 1934, V. 28, Col. 6315. (W)

DYEING: BEHAVIOR OF DELUSTERED RAYONS ON. W. Weltzien and K. Schulze. *Monatsch. Seide Kunstseide*, 1933, V. 38, P. 445–9, 509–11; *Chim. & Ind.*, V. 31, P. 1178; *Chem. Abs.*, 1934, V. 28, Col. 5988. (W)

DYEING: BEHAVIOR OF MAT AND SUPERMAT RAYONS IN. W. Weltzien and K. Schulze. *Mitt. Textilforsch. Krefeld*, 1933, V. 9, P. 51–9; *Chem. Abs.*, 1934, V. 28, Col. 5988, 6570. (W)

DYEING WITH INDIGO AND OTHER VAT DYES: NEW IMPROVED METHOD OF. Franke. *Z. ges. Textil-Ind.*, 1932, V. 35, P. 479–80.

New vat dye prepns. can be obtained by evapg. to dryness mixts. of vat dyes with sulfite cellulose waste liquors or salts of ligninsulfonic acids with or without the addn. of Turkey red. These vat dye prepns. when brought into contact with H_2O immediately form colloidal solns. or suspensions. They can be added directly to the dye bath. Water-sol. ester salts of vat dyes, such as are obtained by treating leuco vat dyes with $ClSO_3H$ in the presence of a tertiary base, undergo no overoxidation if water-sol. thiocyanates were added to the developing bath. The loss of color which some textiles dyed with vat dyes undergo during the bucking operation and which can be explained by the presence of reducing agents formed in the interaction between the strong alkali and the cellulose can be prevented by adding to the bucking liquor quinones of the benzene series or compds. which form quinones in alk. solns. (Copied complete from *Chem. Abs.*, 1934, V. 28, Col. 7019.) (W)

IV. RESEARCH METHODS AND APPARATUS

HUMAN HAIR AS A MEANS FOR MEASURING MOISTURE. (German.) W. D. *Die Kunstseide*, 1934, V. 16, P. 222–3.

The properties of the hair and the principal errors involved in the use of hair-hygrometers are discussed. Certain precautions are necessary in order to get reliable readings. The diagrams of two hygrographs working under identical conditions agreed sufficiently well for practical purposes. (S)

ILLUMINATION ADAPTED TO PHOTOGRAPHY AND LOW-POWER MICROSCOPY: A NEW SOURCE. Wilbur D. Courtney and Ralph Schopp. *Sci.*, 1934, V. 80, P. 189.

The apparatus is a glass tube filled with a combination of gases which may be varied to control the spectrum range and which functions in very much the same fashion as the familiar neon lamp. It is intended for use for low power photography of small opaque objects and for use with the binocular stereoscopic microscope. A step-up transformer on the 110-volt lighting circuit supplies a potential of 2,000 or more volts across electrodes fused into each end of the tube. For the purposes mentioned the glass tube was shaped into a number of close, circular turns, forming either a single or double spiral. Such a spiral with three turns has been found satisfactory for use with the microscope. The inside diameter of the unit should not be less than two inches. This type of lighting is particularly good because of the absence of intense heat which would damage lens mountings or the specimen itself. The intensity of the light source is very even over the entire area so that good lighting of the subject is obtained without manipulation and the shadow intensity is easy to control. There is also no flare, such as is found in some types of incandescent lighting. The cost of this type of unit is under ten dollars. (S)

MICROSCOPIC EXAMINATION OF TEXTILES: NEW OPTICAL INSTRUMENTS FOR THE. G. G. Reinert. *Monatschr. Textil-Ind.*, Trade issue III, 1934, V. 49, P. 73–5.

Eleven new instruments are shown and described which are useful in the microscopic examn. of textiles. (Copied complete from *Chem. Abs.*, 1935, V. 29, Col. 350.) (W)

Optical Instruments Prove Valuable to Textile Industry. W. L. Webb. *Tex. Bull.*, 1934, V. 46, P. 6, 12; *Chem. Abs.*, 1935, V. 29, Col. 350. (W)

Reflective and Transmissive Properties of Diffusing Media: Equipment for Measuring the. H. J. McNicholas. *B. S. J. Rsch.*, Aug. 1934, P. 211–36.

The construction and operation of equipment are described for studies of the diffusion and absorption of light by materials such as textiles, papers, paints, enamels, and other diffusing media for which measurements of colors, gloss, transparency or optical density, hiding and tinting powers, or similar properties, are required. Means are provided for the precise control of the directional and spectral distributions of light incident on the sample and for the measurement of the corresponding distributions of diffused light. The equipment includes two separate illumination units, one for completely diffused illumination of the sample and the other for unidirectional illumination at any desired angle of incidence. Light reflected or transmitted by the sample under either type of illumination is measured for any desired direction of observation by visual photometric or spectrophotometric methods. (Copied complete from the *Eastman Kodak Abs. Bull.*, Nov. 1934, P. 406–7.) (S)

Correction

The abstract on Rayon Identification published in this section last month was incorrectly credited to "A. S. T. M. Rayon Sub-Committee." The correct reference is as follows:

Rayon Identification. A. A. T. C. C. Rayon Sub-Committee. *Am. Dye. Rptr.*, 1934, V. 23, No. 17, P. 241–6.

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Aluminum: Importance of—in Textile Technology. Arthur H. Pettinger. *Am. Dye. Rptr.*, 1934, V. 23, P. 605–7; *Chem. Abs.*, 1935, V. 29, Col. 350. (W)

Rustproof Steels in the Textile Industry. Pötter. *Monatschr. Textil-Ind.*, Trade issue III, 1934, V. 49, P. 63–5; *Chem. Abs.*, 1935, V. 29, Col. 350. (W)

Book Review

The Advance of Science. Edited by Watson Davis, Director, Science Service. Doubleday, Doran & Co., Inc., Garden City, N. Y. (1934). 400 pp.

In terms familiar to the layman the book outlines the extent to which knowledge of man and nature has now advanced in each of the major fields of scientific endeavor. Where background is necessary to understand the most recent scientific progress, it has been included. The volume is the work of the editorial staff of Science Service, a non-profit corporation, organized in 1921, for the popularization of science. (C)